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Experiences in developing multi-technology TMN systems

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ABSTRACT

Integration of management systems across technological and administrative domain boundaries is a necessary prerequisite for automating or optimising service management. Despite many years of standardisation effort the number of management technologies and interface specifications seems to continue to increase. An architectural approach to integrated network management, therefore, cannot be based on any single architecture or technology, but must instead be based on recognition of diversity and interoperability. The TMN-architecture is basically such an integration architecture, although OSI is sometimes assumed to be the only realisation option.

This paper presents experiences with the approach taken to realise integrated network management in the European ACTS project Prospect (project number AC052). Several layers of integration have been realised, including multi-vendor and inter-domain management, and several management technologies have been integrated, namely CORBA, OSI and SNMP.

BACKGROUND

At the NOMS'96 conference the RACE project PREPARE presented the development and validation of a TMN-based inter-domain management architecture [Lewis96]. The paper in particular reported on issues related with multi-vendor TMN - i.e., TMN-platforms from multiple vendors - and multi-TMN configurations - i.e., multiple network operators and owners. This work was mainly validated based on OSI/CMIP.

In Prospect, which is a follow-up on PREPARE, a more broad validation takes place, in terms of management protocols and technologies, but also in terms of the "vertical scope" of management. PREPARE was mainly concerned with managing communications, whereas Prospect also is concerned with managing information services working on top of the communication infrastructure. The range of management technologies include OSI, SNMP, CORBA as well as internet, Web, Java, and others. The range of architectural inputs is extended to include also CORBA/OMG and TINA [Lewis97].

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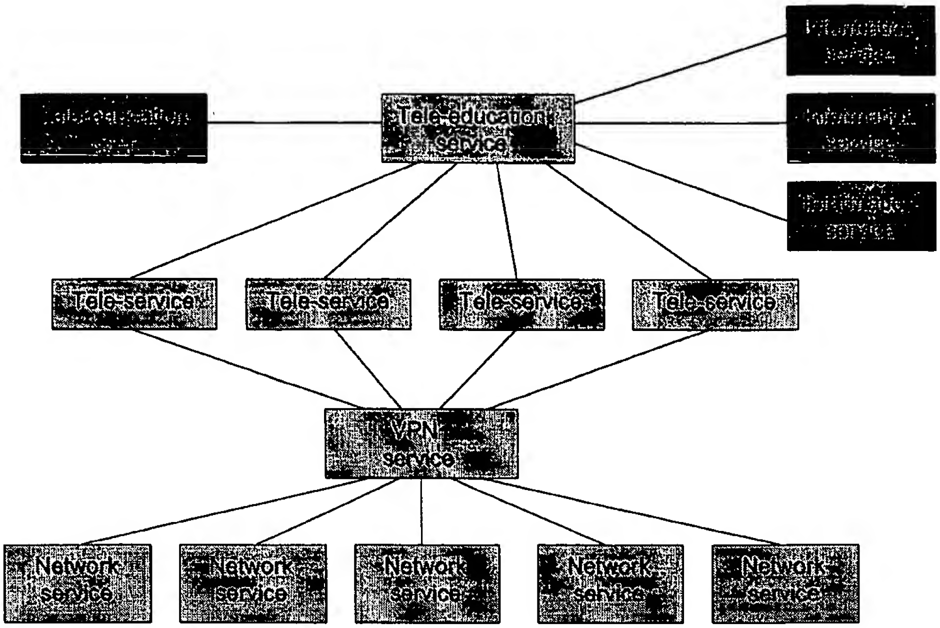
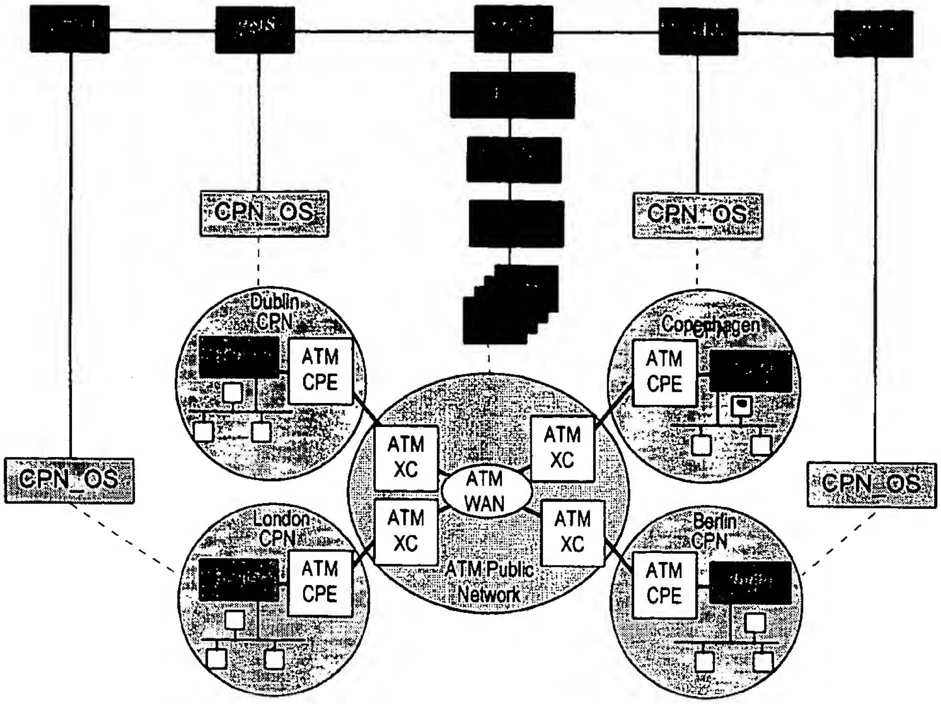


THE PROSPECT SERVICES

The Prospect consortium has set up a pan-European network infrastructure, composed of public and customer premises networks (LANs). The role of the integrated network management system presented in the following is to provide integrated, end to end management of this infrastructure. The system provides corresponding management services to a set of IP-based multi-media tele-services, delivered to users located in the diverse Customer Premises Network (CPN) in the form of an integrated tele-education service package [Lewis97]. The main challenge to deal with in order to realise integrated network management is heterogeneity. Heterogeneity means that “things” are different in some respect. “Things” may be network elements, management systems, components and functions, etc. Differences may be in various respects. Of these, our primary concern is derived from characteristics of an open telecom service market: *administrative differences*, caused by different owners each defining and enforcing their own policies, such as access control and accountability; *technological differences*, caused by differences in communications technologies; *(service) model differences*, which is the result of deploying components for different purposes and applications. One of the results is that different components will offer different services to its users. Another result is that the same service may be offered by different components, in a way that is difficult to discover.

To deal with the heterogeneity, the overall system architecture is based on a distinction between the three types of domain, which reflect the three types of heterogeneity that characterise the network infrastructure: *administrative domain*: the network infrastructure is partitioned into administrative domains, representing the owners of the various parts of the infrastructure; *(network) technology domain*: the various administrative domains encapsulate diverse network technologies; *(management) model domain*: the various network technology domains are manageable by diverse model abstractions and capabilities. To bridge the boundaries between these types of domain an associated set of gateway functions are defined: administrative gateways, technology gateways, and model gateways. Administrative gateways are defined to control interactions across administrative domain boundaries. Management technology gateways are developed to adapt between the various technologies that are present in the heterogeneous network infrastructure and the chosen communications technology. (One example of technology gateways is described in detail later). Likewise, management model gateways are developed to adapt between the management model domains and the abstractions which are defined in order to mask the network heterogeneity.



THE PROSPECT NETWORK

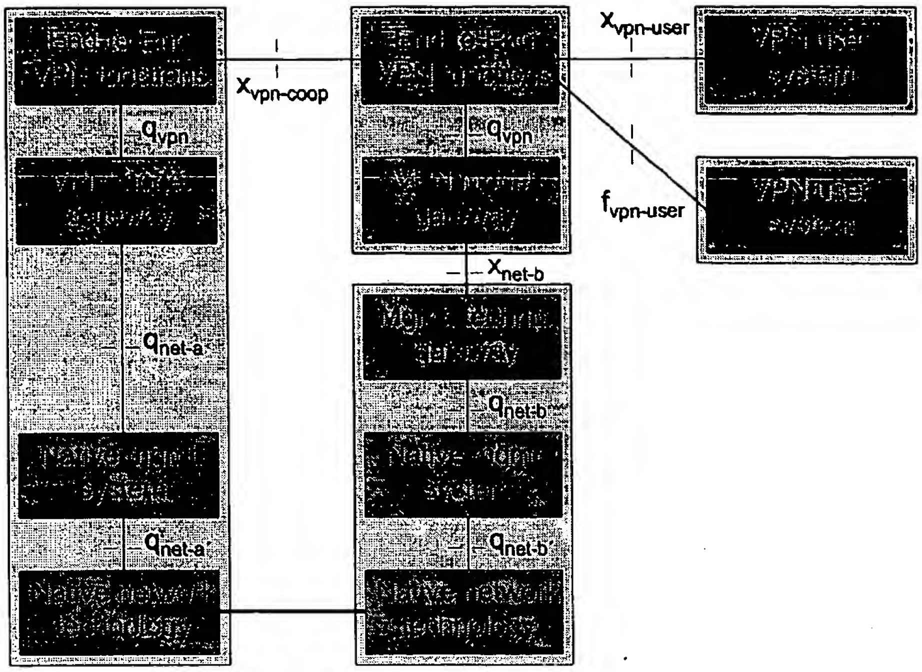
The figure above illustrates the key components of the integrated network management system implementation, and sets the scope for the work presented here. Three components are to be highlighted: the ATM network and its associated TMN OSs (S_OS, N_OS, QA); the VPN management system components (VPN); and the gateway mediating management information communications between the two first systems (Gateway).

All management components of the system shown in the figure are developed by the Prospect consortium. The public network domain part, managed with a TMN-structured system, provides for external access via a CMIP-based TMN X interface for ATM VP service management by the customer (i.e., the VPN provider).

A management technology gateway (CMIP/CORBA interaction gateway) is located in the public network (PN) domain. In the VPN domain management model gateways are located which adapt (transform) the ATM VP service management model to the VPN domain abstraction.

This in turn serves the end to end VPN management functions (denoted VPN in the figure), which are accessible from the customer's system. Similar arrangements are made for the VPN to be able to manage the customer premises networks (CPN), which have SNMP management facilities.

These components, which will be described in more detail in the following, all contribute to the integration of network management. In particular: the VPN is mainly concerned with multi-owner, multi-technology and service management integration; the ATM TMN components are mainly concerned with multi-vendor integration; the CORBA/CMIP gateway is concerned with multi-technology integration; the CPN management component is mainly concerned with multi-vendor and multi-technology integration.



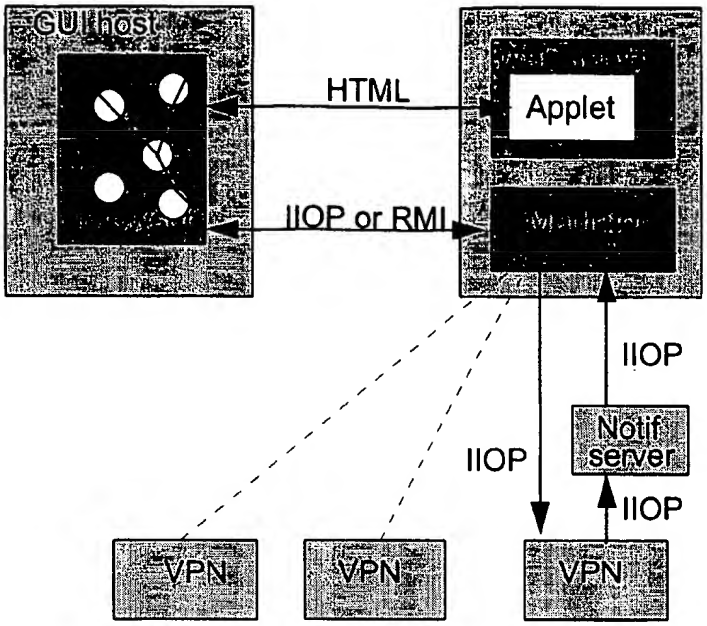
VIRTUAL PRIVATE NETWORK

The basic role of the VPN is to provide an integrated management service allowing users to manage their communications on a global scale, and based on the assumption of a global, heterogeneous network infrastructure. Therefore, the VPN is a good example of an integrated network management system, and furthermore, it has also commercially attracting characteristics [Louis95]. User access to the VPN management services can be mediated by human-machine interfaces (GUI), and by machine-machine interfaces, for automatisation purposes. Prospect's VPN service is designed for decentralised control and co-operation among VPN providers in order to establish broader scope VPN services.

For the realisation of the VPN service, a CORBA 2.0 compliant ORB implementation is used. The object oriented architecture of CORBA is suited for the implementation of systems based on distributed architectures. The object based nature of CORBA ensures a high level of maintainability and allows the development of more extensible applications. The focus on well-defined language-independent interfaces, as the starting point for implementation, facilitates the separation of large designs into smaller and more manageable components, and enables the development of reusable components.

The COS Naming service (specified by OMG) is used to provide location transparency in the distributed VPN system. The naming structure is hierarchical and the service can be federated, which is a mandatory feature when used in a distributed multi-domain management system. In Prospect, the Naming Service is used in a way which balances the convenience of having globally accessible objects with the performance and security issues. Each site can run a local instance of the Naming Service to handle local objects, and still gain/provide access to global objects by using a root-level entry, which points to the global instance (or set of instances) of the Naming Service.

An important aspect of CORBA based applications is the granularity of CORBA objects. CORBA is ideal for providing access to 'big' 'low granularity' controller objects offering complex functionality (e.g. wrapping legacy application, CMIP agent role). Whether CORBA is suitable for high granularity object models is more doubtful. Use cases which involve a huge number of CORBA objects will result in a lot of design problems concerning transactions, persistency, security, location etc., which may lead to an unacceptable performance of the application.



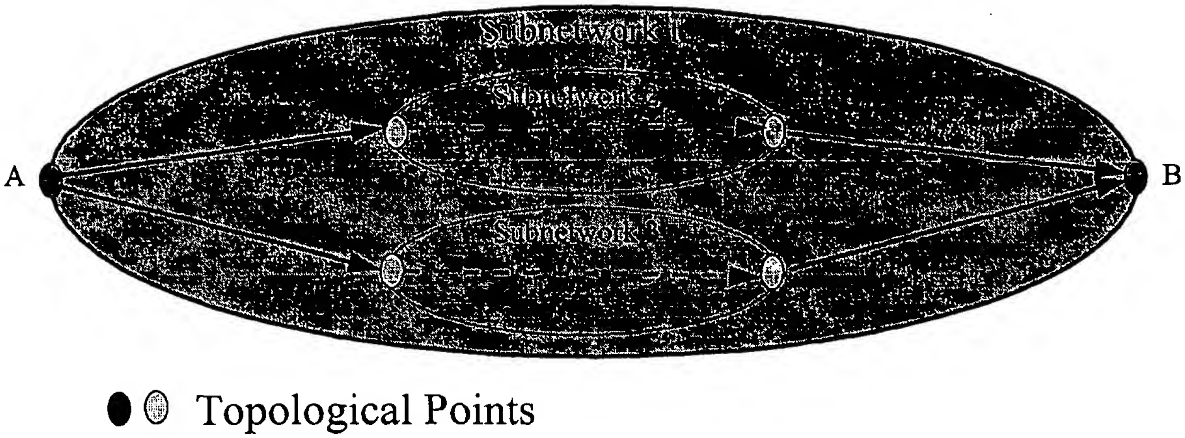
WEB-BASED USER ACCESS TO THE VPN

The VPN Management system depends, as mentioned ealier, on three types of gateways in order to bridge the differences in the heterogeneous network environment. One technology (CORBA/CMIP) gateway is described elsewhere in this paper. The administrative gateway, which presents the $X_{vpn-user}$ interface to the customer, is an implementation of the Service Subscription Model from the TINA Service Architecture. It is a reusable component that is used on various levels of the Prospect system, and it has been adapted to the specific needs of the VPN system as a connection management service, as opposed to a "traditional“ information management service. This gateway enables the VPN customer to use the VPN service in way that is as generic and service-independent as possible.

The management model gateway is intended to alleviate the differences in the various management models (SNMP/CMIP) in order to be able to handle the different network technologies in a uniform way. The funtionality needed for this is divided into three parts: (1) the handshaking procedure, which allows cooperation between domains that have different technology-specific demands, (2) an object that presents each domain's VPN system with exactly the level of end to end information it needs, and (3) an object which handles low-level API peculiarities.

Java, CORBA and Web technologies are used to visualise information and behaviour of the VPN application. The VPN GUI is implemented as a Java applet, which enables distribution of the GUI to all computers running a standard web browser. The Web technology facilitates the distribution of the customer user interface and access software for a CNM service to a user, by use of applets which can be downloaded from the providers Web server.

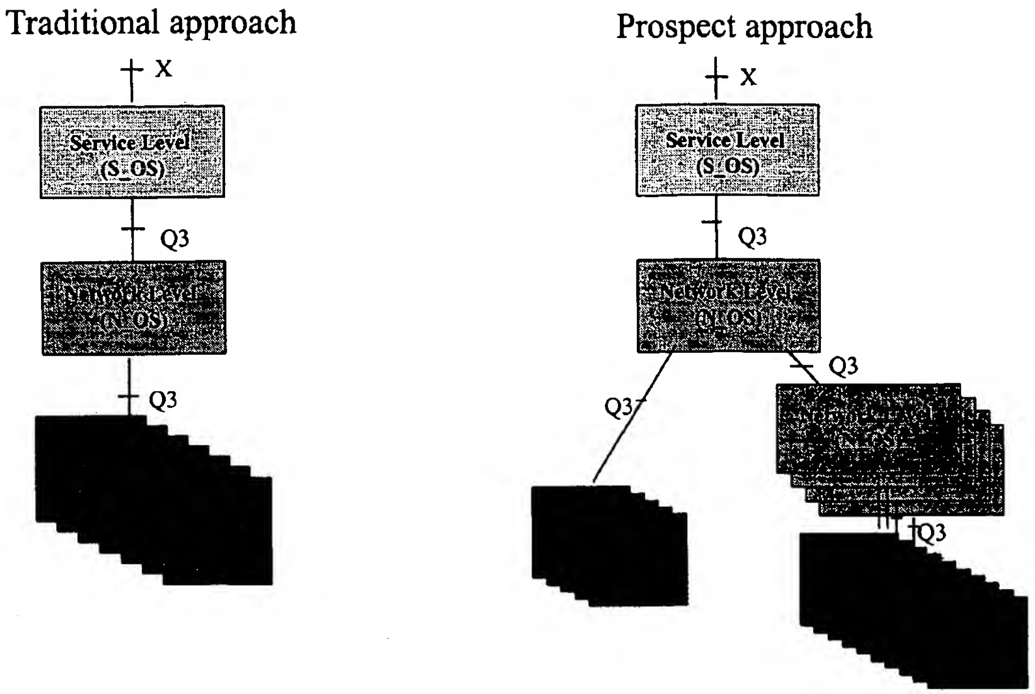
The VPN GUI is based on configuration, fault and QoS management information from the VPN application. The information is provided by APIs in the VPN application and by asynchronous events from the VPN. When changes occur in VPN resources, notifications are emitted to a notification server, which distributes the notification to subscribing clients (e.g. GUI). The notification server is inspired by ITU CMIS event management and COSS event service specifications.



ATM NETWORK MANAGEMENT

The VPN services offered by the VPN management system is based upon an ATM network infrastructure, where the network infrastructure is constituted by a number of interconnected ATM cross connects at four European sites: Berlin, Dublin, London and Copenhagen. Each of the four sites represents a separate administrative domain within the public ATM network. The network OS'es at the four administrative domains cooperates in order to provide a fully manageable pan-European VP layer network domain. The ATM VP management service offered by the public network is provided through an OS giving a top level view of the VP layer network domain, where each of the separarate administrative domains is viewed as a subnet partition in the VP layer network domain. Prospect applies a distributable object model, where the management and control of the subnetwork partitions can be arbitrarily distributed among the coorporating network OS'es. The location of the OS giving the top level view on the combined network is configurable and the service can be moved to or duplicated by other OS'es giving their own view of the network.

The public ATM network VP service is fully implemented within the CMIS/CMIP technology domain using the Q3ADE TMN development tool. The service provided by the network OS'es to adjacent or higher layer management systems is offered through TMN X interfaces. The choice of the CMIS/CMIP technology to implement the public network services is to some extent historical, since the public network management system is based on the system and concepts developed in PREPARE [Lewis96], but mostly due to the structure of the problem domain. ATM networks are highly complex and the adopted objects models are very fine grained and results in a huge number of object instances. As explained earlier the current set of services offered within the CORBA domain seems inadequate when dealing with large and fine grained models, whereas CMIS/CMIP with the scoping and filtering capabilities has proven to be a strong technology for such applications. It is however recognised that the ATM VP service users in many cases will be in the CORBA domain. A CORBA/CMIP gateway is therefore included as part of the public network service offering. The network model applied within the public network is based on the ETSI NA43316 Generic Object Model Library (GOM), which has been specialised to the ATM technology. The fundamental idea behind the GOM network model is the break down of subnetworks into subnetworks interconnected by links (as illustrated in the figure above). This decomposition process stops at the lowest level where a subnetwork is "equal" to a crossconnect.



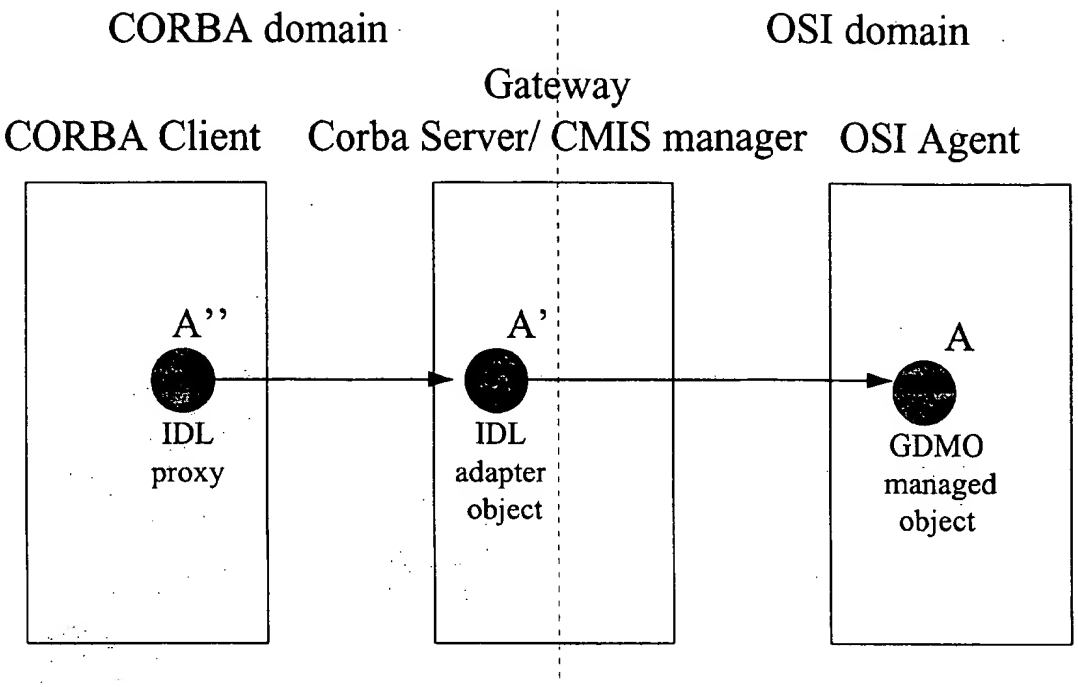
ATM NETWORK MANAGEMENT DISTRIBUTION

The network OS'es assume that the network element level is controllable via Q3 interfaces giving an ITU-T I.751 compliant view of the ATM network elements. This is realised within Prospect by providing I.751 compliant Q-adaptors for the ATM cross-connects constituting the ATM network infrastructure.

The recursive layering of NE-OS and N-OS provides a single entry NE-OS for a given required functionality for the various divisions of the network, and thereby providing facilities for end to end management.

The ETSI GOM library seems to favour a centralised network management, as indicated in the figure above. The issue of the distribution of the network management application both between different administrative domains but also the distribution of the application within an adminstrative domain is in general an area, where the standardisation on the network management issues are falling short. The distribution question is in particular relevant for ATM networks, where the granularity of the object model and the vast number of object instances renders a centralised management application inadequate for large ATM networks. One of the main issues addressed by the Prospect network modelling work, has therefore been to specialise the GOM model to promote a decentralised view of the network mangement application in favour of the traditional view of a centralised network management application controlling a number of network element agents.

An issue when implementing a decentralised network mangement application is to allow for a distributed route determination process, and to allow for subnetworks at higher partitioning levels to make qualified route decisions concerning routes through an opaque subnetwork at a lower partitioning level. The concept of opaque subnetworks and associated concepts for the handling of these within a network OS provides the means to distribute the implementation of the network service at will. In order to facilitate opaque subnetworks Prospect has added route managed objects to the network model. Within the partitioning hierachy the route managed object allows subnetworks at higher partitioning levels to query route information from subnetworks at a lower partitioning level in order to make qualified decisions about which subnetworks a requested connection should be routed through.



CORBA/CMIP INTERWORKING

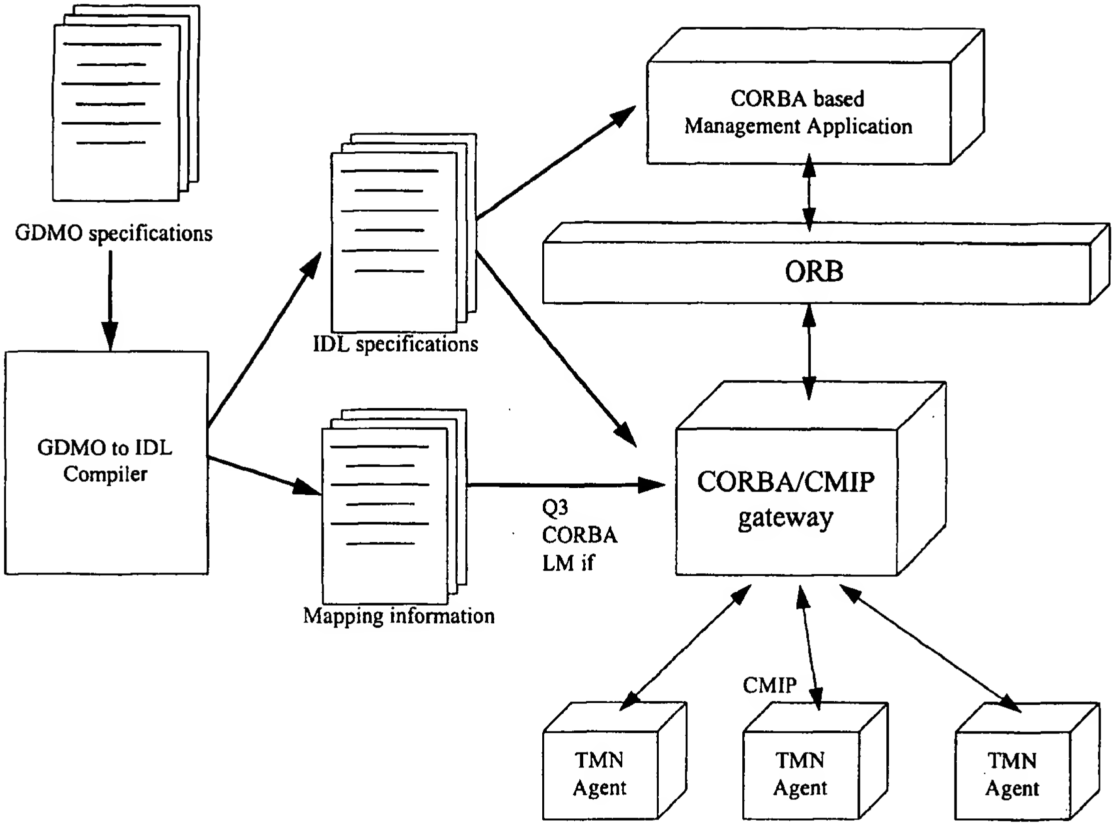
Within the overall system a technology gateway is used to bridge between the CORBA and the CMIS/CMIP communications technology domains. The CORBA/CMIP gateway allows the CORBA VPN functionality to access and control the service provided by the public CMIP based ATM VP service provider.

The CORBA/CMIP gateway maps the services offered by the ATM VP service management system into the CORBA technology domain. With the use of the gateway the ATM VP service can be seen as any other CORBA based service offering. The change in management technology hereby becomes invisible to the VPN functions.

The service offered by the ATM VP service management system via its CMIP/CMIS based TMN X interfaced is defined with the GDMO model accessible through the interface. The gateway represents this service in the CORBA domain, by translating the GDMO model into equivalent IDL definitions and offering these IDL interfaces at its CORBA server interface. CORBA invocations on the IDL interfaces are translated into equivalent CMIS requests by the gateway and forwarded to the underlying ATM VP Service management service. The general approach is illustrated in the figure above, where a CORBA based client will create an IDL proxy object which will connect to the corresponding IDL adapter object in the gateway process. Any invocation on the IDL adapter object in the gateway process will be translated to CMIS request and issued to the GDMO managed object in the OSI Agent to which the IDL adapter object corresponds.

The rules for mapping the GDMO specifications into equivalent IDL definitions are defined by the Joint Inter-Domain Management working group (JIDM).

JIDM is an activity jointly sponsored by X/Open and the Network Management Forum. The JIDM project was initiated in a response to the perceived need to provide tools that would enable interworking between management systems based on different technologies, notably OSI and SNMP network management and CORBA-based management frameworks.



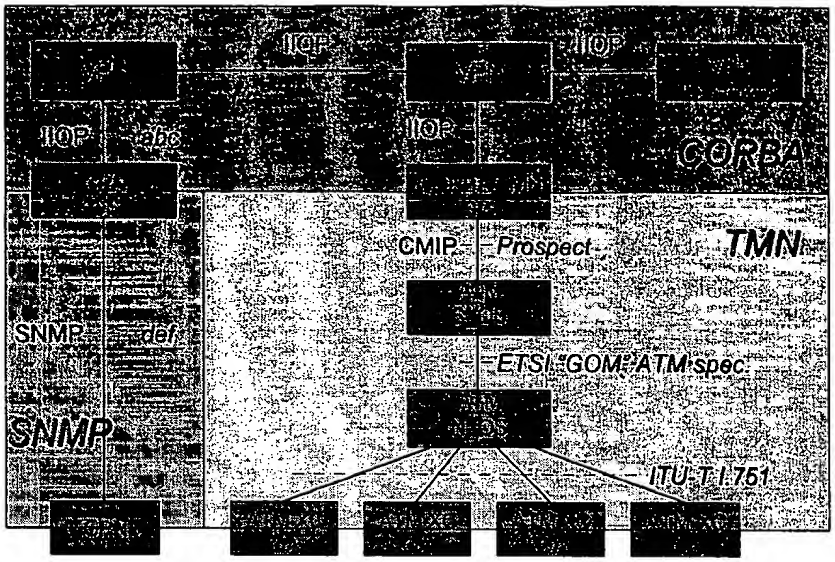
CORBA/CMIP GATEWAY

The gateway work within Prospect was divided into two stages. The first stage involved the specification and implementation of an initial gateway, which supported the basic CMIP-CORBA interworking required in the integrated network management system presented earlier.

The second stage involved the specification and implementation of a gateway, which addressed more advanced aspects of CORBA-CMIP interworking, such as event handling, name resolution, scoping, and filtering. The second stage of the gateway work included the use of the CORBA Dynamic Skeleton Interface (DSI) and a GDMO to IDL compiler capable of producing translation tables (as illustrated in the figure above).

The use of the DSI and automatic translation tables eliminated the need for the gateway process to have compile-time knowledge of the GDMO models of the underlying OSI agents. The second stage therefore provided the implementation of a GDMO model independent and dynamically re-configurable gateway process. The technology gateway hereby to a far extent becomes invisble to the service users in the CORBA domain. Any new service offering in the CMIP domain can be made visible in the CORBA domain by updating the gateway with the GDMO information model attached to the new CMIP based service. Doing so will make the CMIP based service available in the CORBA domain as any native CORBA based service.

The CORBA/CMIP gateway in itself provides both CMIP and CORBA based management interfaces, which allows for remote and dynamic update of the mapping information. The gateway can consequently be managed either by entities in the CORBA domain or by entities in the CMIP domain. Within Prospect the CORBA/CMIP gateway belongs to the public network domain, which with the gateway makes the public network services available in the CORBA domain. The gateway could however also have been placed in the service user domain (the VPN), or in the administrative domain of a third party service provider offering technology gateway services.



CONCLUSIONS

The experience gained from developing the integrated network management system presented here shows that it is indeed possible to provide the types of network management integration required to enable automated end to end communications management across the domain boundaries of a heterogeneous network infrastructure. It also shows that CORBA is feasible for developing such systems at the service management layer, and that the application of CORBA does not violate any TMN architectural principles. Rather, CORBA is becoming a realistic TMN realisation technology. However, OSI-based TMN is still superior in some respects, due to its ability to handle large numbers of managed objects (e.g., by OSI's naming scheme and by encapsulation), and due to the large number of management functions that are standardised and available in commercial TMN platforms. This is one of the reasons why gateways are central components for integrating network management. Even more so, as SNMP and OSI agents are deployed in a huge range of existing and installed networking equipment.

Our experience also shows that TMN is a feasible integration architecture. The functionality of the system can be easily explained in terms of TMN function blocks, and the various gateway types needed also maps easily onto TMN building blocks: technology gateways are basically Q Adaptors, model gateways are Mediation Functions or Information Conversion Functions, and administrative gateways functions are functions located near the X interface. The development work was undertaken by several companies, each developing a set of the components described here. Driven by common goals and a clear division of labour, in accordance with Prospect's "service value-chain", it was even possible to integrate the various components in a relative unproblematic manner. In the remaining time of the project this system is being extended further, for example, integrated fault and performance management functionality will be added, and CMIP/SNMP gateways will be included, and end-user access to management information through a TMN WSF with Java and directory gateways will be provided.

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